Seepage into Underground Cavities: Field Experiments

Robert C. Trautz and Joseph S.Y. Wang
Contact: Robert C. Trautz, 510/486-7954, rctrautz@lbl.gov

RESEARCH OBJECTIVES

Water introduced at the land surface during a precipitation event, assuming it migrates through the unsaturated fractured rock to the potential nuclear waste repository beneath Yucca Mountain, Nevada, may potentially enter the more than 100 km of waste emplacement drifts. Over time, seepage water may contact the waste canisters, hasten corrosion (increasing the probability of canister failure), and potentially result in radionuclide migration beyond the canister environment. Because seepage can impact repository performance, it is important to study flow mechanisms and processes that influence seepage.

APPROACH

Liquid-release tests were performed at several sites located in the Exploratory Studies Facility at Yucca Mountain to investigate seepage processes. A fixed volume of water containing dye was released at a constant rate into selected boreholes. A short drift was then excavated at each site using mechanical methods and employing as little construction water as practical to prevent the dyes from washing away during construction. Dye-stained fractures, rock matrix and natural cavities called lithophysae were mapped during construction to document the flow path traveled by the water.

ACCOMPLISHMENTS

Liquid-release tests were performed at five sites in two zones within the Topopah Spring Tuff (Tpt), the host rock for the proposed repository. Four of the sites are located in the middle nonlithophysal zone (Tptpmn), a densely welded, fractured zone containing few lithophysae. The fifth site is in the lower lithophysal zone (Tptpll), containing abundant lithophysae, providing ample opportunity to observe seepage into cavities as large as 0.5 m in diameter.

Dye was observed along individual fractures and fracture networks to a maximum depth of 2.57 m below the release points in the Tptpmn. The dye pattern tended to be asymmetrical, showing a strong downward component of flow (Figure 1a). In contrast, dye was observed in fractures and lithophysae to a maximum depth of 1.37 m in the Tptpll. The dye patterns are more symmetric, with the lateral edges of the wetted area lying about equal distance from the release point (Figure 1b).

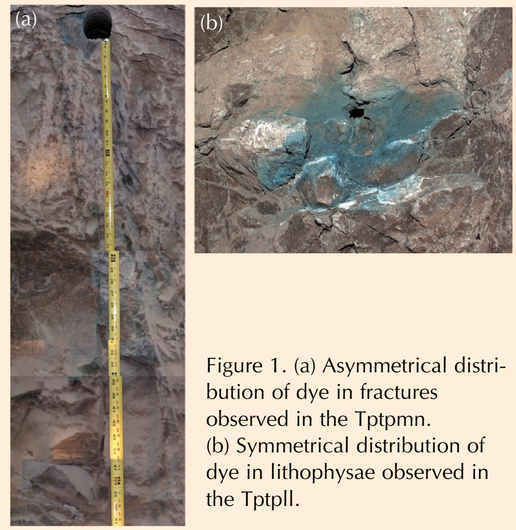

Figure 1. (a) Asymmetrical distribution of dye in fractures observed in the Tptpmn.
(b) Symmetrical distribution of dye in lithophysae observed in the Tptpll.

SIGNIFICANCE OF FINDINGS

The dye patterns suggest that flow through fractures in the Tptpmn is predominately gravity-driven. In contrast, the symmetry of the dye patterns observed in the Tptpll suggests that capillary forces may be more important in this zone. Dye was observed on the walls, ceiling and floor of numerous lithophysae in the Tptpll. There was no evidence, however, that water accumulated and dripped into the cavities even though the liquid-release fluxes applied during the test were 1,000 times greater than the natural flux, estimated at 10 mm/yr.

It is surprising that capillary forces appear to be stronger in the Tptpll because the average air permeability of the Tptpll is greater than the Tptpmn. Typically, capillary forces are less important in higher permeability media than in lower permeability materials. This may indicate that the air permeability measurements performed in the Tptpll represent the interconnected lithophysae (macropores) rather than the smaller fractures where capillary-driven flow will dominate at lower saturations, as evidenced by the symmetrical pattern of dyes. Should this be the case, a multi-continuum model that incorporates the macropores, fracture network and rock matrix may be needed to adequately represent the flow of water, water vapor and air through the Tptpll.

RELATED PUBLICATIONS

Finsterle, S., and R.C. Trautz, Drift seepage in unsaturated fractured rock, American Geophysical Union 1999 Fall Meeting, San Francisco, Calif., Dec. 13-17, 1999.

Trautz, R.C., and J.S.Y. Wang, Evaluation of seep-age into an underground opening using small-scale field experiments, Yucca Mountain, Nevada, 2000 SME Annual Meeting & Exhibit, Salt Lake City, Utah, Feb. 28–March 1, 2000.

ACKNOWLEDGEMENTS

This work was supported by the Director, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, through Memorandum Purchase Order EA9013MC5X between TRW Environmental Safety Systems, Inc., and Ernest Orlando Lawrence Berkeley National Laboratory for the Yucca Mountain Site Characterization Project under Contract No. DE-AC03-76SF00098.